Freshness Monitoring of Packaged Vegetables

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Smart packaging is an emerging technology that has a great potential in solving conventional food packaging problems and in meeting the evolving packaged vegetables market needs. The advantages of using such a system lies in extending the shelf life of products, ensuring the safety and the compliance of these packages while reducing the food waste; hence, lessening the negative environmental impacts. Many new concepts were developed to serve this purpose, especially in the meat and fish industry with less focus on fruits and vegetables.

1. Introduction

Food packaging was developed to serve several purposes such as limiting food loss and preserving food quality for longer periods. Its main functions can be summarized as protection from possible contaminations as it acts as a barrier, communication of the package information about brands and nutritional content, containment, and convenience to accommodate the fast-paced customer's lifestyle [1]. However, continuous changes in customer and industry demands led to the evolution of smart packaging as an alternative to conventional packaging. An important purpose of smart packaging is to trace and preserve perishable goods as much as possible while ensuring safety, reducing food waste and environmental impact through monitoring and sensing. Generally, food loss is considered one of the main issues of concern around the world. It was found that almost one third of the food produced is wasted along the supply chain [2]. In Canada, in 2019, the estimated food loss was worth $31 billion, of which 30% was vegetables [2].

Food waste occurs along different stages in the supply chain, starting with on farm waste as a result of inadequate harvesting and handling, to losses through processing and storage, then in transportation and distribution due to the use of unsuitable facilities, and losses at the retail shops due to limited shelf-life or improper storing. **Figure 1** shows percentages of food losses for different categories, from post-harvest to distribution. Fruits and vegetables are considered a major contributor after the roots, tubers, and oil-breaking corps to food wastage along the supply chain with 21.6% [3]. Apart from the ethical side of wasting food, other problems such as food contamination is an issue of concern. Many deaths over the years were linked to presence of pathogens in packaged food [4]. The economic loss and the environmental depletion of agricultural resources are also major problems that need to be addressed. All of that brought to attention the necessity to take the appropriate measures to ensure control and reduction in these wastage rates. Smart packaging presents a viable solution in such application to reduce the inefficiencies and wastage in the food supply chain [5].
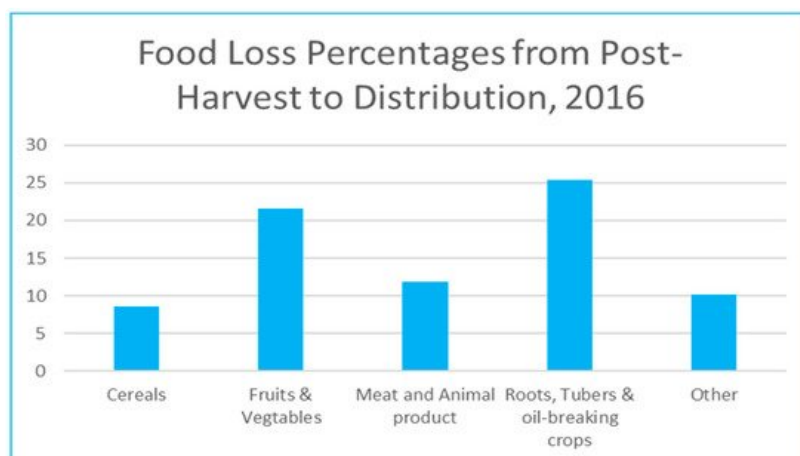

Figure 1. Food loss percentages along the supply chain (Data based on FAO 2019 report [3]).

Many papers were published about the use of smart systems in different food and beverage industries [6]. Some discussed their use in monitoring water quality [7][8][9][10][11]. Other publications focused on freshness detection and control of packaged meat and animal products [12][13][14][15]. Some others were concerned about the freshness of the produce in general [16][17][18][19][20], with less attention and focus to vegetables in specific. However, with the recent increase of illnesses outbreaks related to packaged vegetables [21], the need to have more research on vegetable freshness inside a package in specific became a necessity. This is to avoid food wastage while ensuring the health and safety of the public. Smart systems have a great potential in such application. Smart packaging can be used to monitor the freshness and the quality of the food inside, and also to detect the presence of substances such as Bisphenol A migrating from the plastic package itself that is used in the food and beverage industries [22]. Therefore, with the continuous improvement in smart systems technologies, the possibility of commercial use of smart packaging in the food industry is rising.

2. Classification

In the last two decades smart packaging has become popular especially because it leads the consumer and businesses to make better decisions regarding food quality. It can be further classified into two main categories: intelligent packaging (IP) to monitor the freshness and safety, and active packaging (AP) to keep or improve the quality. IP is defined as one of the packaging systems that plays an important role by providing means of sensing/indicating and communicating the information about the freshness and the safety of the consumed vegetables and aims to prolong the shelf life. This emerging packaging technology, that serves as a barrier against environmental influences such as odors, dust, micro-organisms, facilitates decision making regarding the quality of the packaged food. IP contains smart devices that are capable of tracing and monitoring the freshness of the produce. It can also store and transfer the sensed information to retailers and stakeholders to improve the technology. Intelligent packaging (IP) can be classified into three main categories: sensors, indicators, and data carrier, as shown in **Figure 2**. Each category can be either placed inside or on the package to provide information about each package, or to monitor the environment surrounding the packages [1][23]. In contrast, active packaging (AP) is defined as the system that incorporates active components such as scavenging or releasing objects in response to changes in package headspace to extend the shelf-life of the packaged food. AP can be further classified depending on the objects used inside the package into scavengers and releasers. Scavenging objects concern the capture of excess moisture, odors, and gases such as moisture absorbers, oxygen scavengers, and odor absorbers [23]. The releasing objects are usually emitters/generators that release objects such as antimicrobials agents, carbon dioxide emitters, and antioxidants [23].
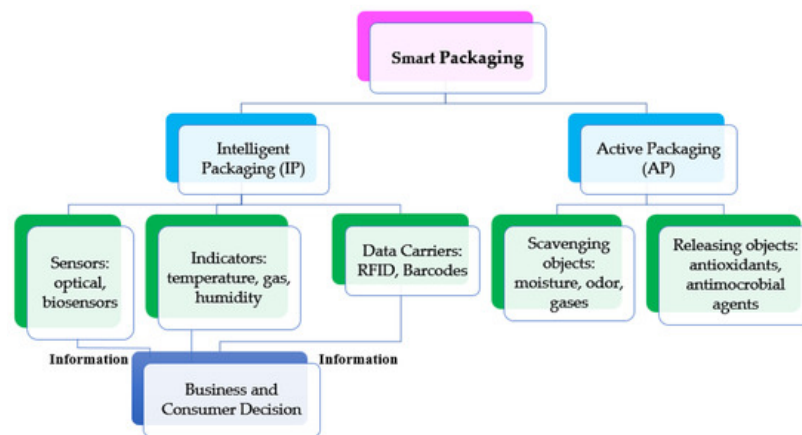

Figure 2. Smart packaging system classification.

3. Conclusions

The smart packaging systems provide potential solutions to the conventional packaging problems such as food loss and contamination. For packaged vegetables, the most important factors to monitor as a part of freshness assessment of vegetables are the ratio of oxygen and carbon dioxide inside the package, ethylene response, pathogen presence, and temperature, which has a huge effect on pathogens growth rate, chlorophyll content, and humidity. Tracking these parameters can be done through intelligent systems such as sensors (optical, bio, gas, and humidity), indicators (TTI, gas and humidity, and freshness), or by data carriers (RFID tags and barcodes). Adjusting these parameters can be done using active packaging such as using scavenging objects (oxygen or carbon dioxide scavengers, moisture absorbers), or releasing objects (oxygen or carbon dioxide emitters, antioxidants, antimicrobials). However, the challenges facing this industry in terms of complexity of legislations and regulation, cost, privacy concerns, and sustainability of the systems

used are inhibiting mass-production of such smart systems. Therefore, collaboration between the researchers, industries, regulatory agencies, and the consumers will allow for further development of smart packaging systems.

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